

MONITORING OF ELECTRICAL END-USE LOADS IN COMMERCIAL BUILDINGS

MARK MARTINEZ
Energy Management Engineer
Southern California Edison
Rosemead, CA

TAGHI ALEREZA
Principal
ADM Associates
Sacramento, CA

DANIEL MORT
Energy Engineer
ADM Associates
Sacramento, CA

ABSTRACT

Southern California Edison is currently conducting a program to collect end-use metered data from commercial buildings in its service area. The data will provide actual measurements of end-use loads and will be used in research and in designing energy management programs oriented toward end-use applications.

The focus of the program is on five major types of commercial buildings: offices, grocery stores, restaurants, retail stores, and warehouses. End-use metering equipment is installed at about 50 buildings, distributed among these five types. The buildings selected have average demands of 100 to 300 kW. The metered end-uses vary among building types and include HVAC, lighting, refrigeration, plug loads, and cooking.

Procedures have been custom-designed to facilitate collection and validation of the end-use load data. For example, the Load Profile Viewer is a PC-based software program for reviewing and validating the end-use load data.

The primary considerations in selection of buildings were: building type, electric demand, the region in which the building is located, and cooperation of the building manager. The electric demand of the buildings range from 100 to 300 kW. Table 1 shows the distribution of building types included in this study.

Building Type	# in Study	Percent of Sample	# of Channels per Site
Grocery	16	28	8
Office	12	21	8
Restaurant	16	28	8
(Full service)	(12)	(21)	8
(Fast food)	(4)	(7)	8
Retail, dry goods	10	18	4
Warehouse, unrefrig.	3	5	4
	----	----	
TOTAL	57	100	

Table 1 Distribution of Building Types

INTRODUCTION

Southern California Edison is sponsoring the collection of electrical end-use load data in 57 commercial buildings. The purpose is to obtain actual measurements of end-use load profiles for research and data analysis.

This data collection project has been given the name RESA as an acknowledgment to the four companies that have been a part of the project. The four companies are: Robinton Products, Inc. (RPI) of Sunnyvale, CA (electrical transducers and ALICE 5), Electrical Systems Testing (EST) of Garden Grove, CA (installation contractors), Southern California Edison (SCE) of Rosemead, CA (project sponsor), and ADM Associates (ADM) of Sacramento, CA (site engineering and data validation).

SITE SELECTION

The sites selected for this study are a subset of a group of 375 buildings for which detailed on-site surveys had been performed. The surveys contain information about the buildings type, size, operational characteristics, and electrical equipment.

All sites are located in SCE service area and range from as far north as Tulare, south to Mission Viejo, east to Palm Desert, and west to Ventura.

MONITORING METHODOLOGY

The monitoring methodology is designed to collect the major end-use load types for each building type. Not all electric loads are monitored since it can often take much expenditure in time, equipment, and effort to collect these data. The end-uses that have been selected as significant contributing factors to the total load include: lighting, HVAC, refrigeration, plug-load, exhaust, and cooking. Table 2 shows the end-use monitored in each building type.

Grocery	Office	Restaurant	Retail	Warehouse
Lighting	Lighting	Lighting	Lighting	Lighting
HVAC	HVAC	HVAC	HVAC	Total
Temp.	Temp.	Temp.	Temp.	
Refrig.	Plugs	Refrig.	Total	
Total	Total	Exhaust		
		Cooking		
		Total		

Table 2 End-Use by Building Type

The selection of HVAC as an end use is an important consideration since cooling loads have a significant impact on the peak demands in SCE's service area. Most of the air conditioning systems monitored in this study are packaged units.

Buildings with built-up HVAC systems have the chiller and cooling tower monitored separately from the air handler. The lighting monitored is generally from the primary lighting system which is used in a building and in some cases may also include the outside lighting. The refrigeration loads monitored in grocery stores and restaurants are from the compressors and cooling tower. The exhaust monitored in restaurants comes from the kitchen exhaust hood fans and any evaporative coolers which supply make-up air.

In the buildings where the HVAC is measured, temperature is also measured. Measurement of the indoor temperature is a secondary measurement used as an aid when validating the HVAC loads. In circumstances where the HVAC system is an electric heat pump, the temperature probe is placed in the supply duct of the unit. This allows the mode of operation (heating or cooling) to be determined.

The outdoor temperature is also collected at several locations, each in close proximity to a group of monitored buildings. Ambient dry bulb temperature and relative humidity data are combined with the end-use data to enhance analysis capabilities.

EQUIPMENT INSTALLATION & VERIFICATION

Generally there are three types of measurements made at each site. They are the electrical end-uses, the total electric billing load, and temperature. The electrical energy used

by the end-uses are measured with Robinton Electric ARM watt-hour transducers; the total electric billing load uses a Pulse Initiating Watt-Hour Meter; and the temperature is measured with a temperature transponder. The electrical end-uses are typically located in different parts of a building. To bring the measurements together at one central location, a set of power-line carrier signal transponders and receivers are used. The central piece of equipment at each site is the Load Profile Recorder.

Before an installation is started, site visits are made to collect specific information about the building wiring and end-use sizes. Electrical circuits to be monitored in a building are first identified using the labeling on the electrical panels. Then verification of the loads on the designated circuits may include switching breakers on and off, following conduit, or using a current tracer. A single line diagram is made showing the major electrical systems in the building. From the diagram a monitoring plan is designed. An example of a single line diagram is shown in Figure 1.

The installation of equipment begins with the watt-hour transducers. The watt-hour transducers utilize current transformers to step-down the current used by the end-use. The current transformers are donut shaped and wire wound around a solid core. The circuits to be monitored must be turned off and disconnected to insert the circuit wiring through the center of the current transformer. The watt-hour transducers output pulses that are proportional to the electrical energy use measured. There is a multiplying factor

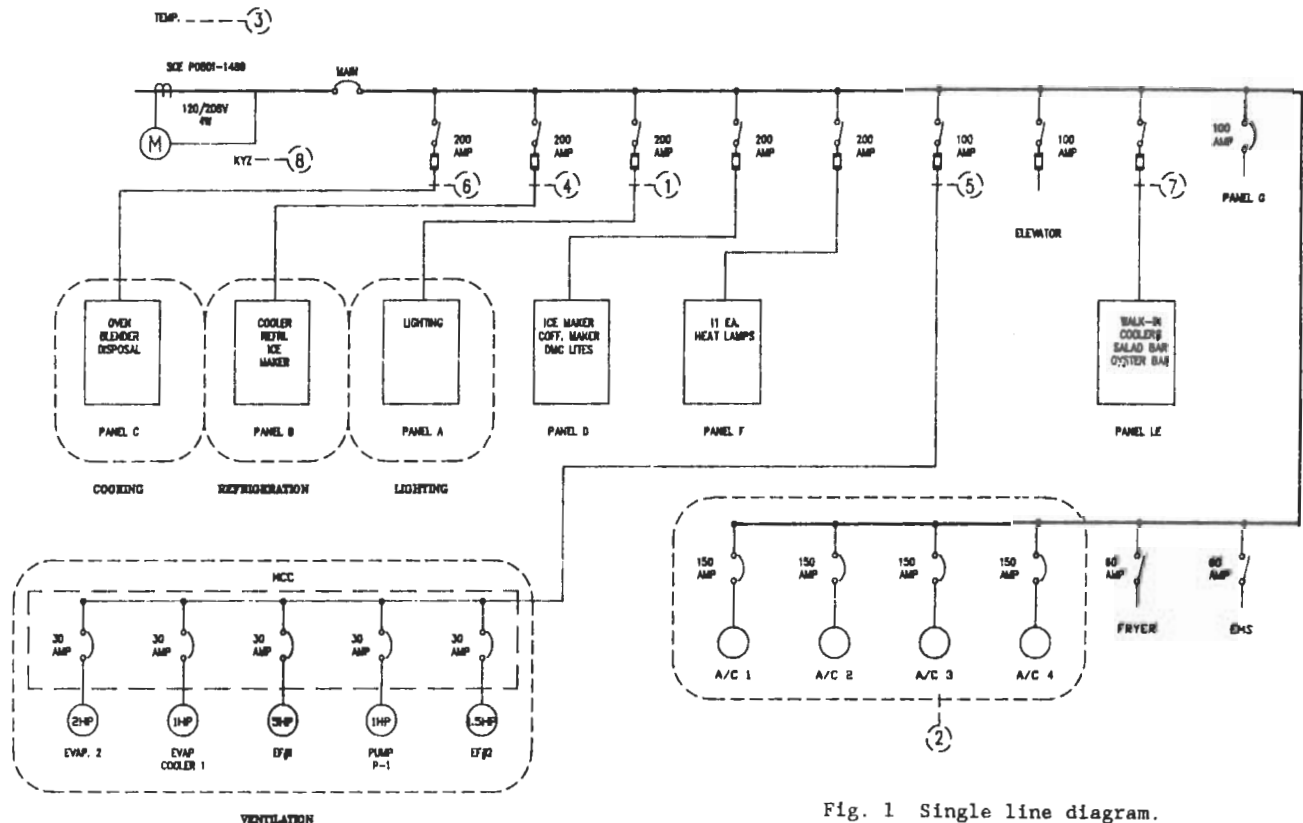


Fig. 1 Single line diagram.

corresponding to each watt-hour transducer, the current transformer winding ratio, and the ratio of any potential transformers used. Potential transformers are used in buildings with 277/480 Volt service.

Power-line carrier transponders and receivers are used to send signals on the building wiring from remotely located measuring equipment to a centrally located receiver. The transponders send their signals approximately once every minute (but send the last ten minutes of pulse information), while the receivers collect the information and delay outputting the pulse data for fifteen minutes. Therefore pulse data on channels using the receivers are skewed fifteen minutes from channels that are wired directly to the recorder.

The data is stored on site in Load Profile Recorders. Pulse information is stored in memory chips with up to four channels of data per recorder. The recorders and receiver are generally mounted in the main electrical power room. The recorders communicate with a central computer station via phone lines. The recorders must be initialized over the phone lines with pertinent information such as an identifying code, phone number to call, how often they should call the central computer, etc.

The installation of the monitoring equipment at each site took from two days to two weeks depending on the complexity of the wiring. The installation process included mounting metering boxes, running conduit, opening panels and placing current transformers on circuits, and all associated wiring, connection of the phone lines to the recorders, and on site initialization of recorders.

Post installation verifications were performed at each of the site installations. Each site was visited and measurements were made on each channel. Channels with watt-hour transducers used a special hand-held terminal to receive a direct read-out of the load power draw on each of the phases of the measured circuits. Most of the channels in this study monitor electrical loads supplied by three phase power. The direction the current transformer is placed on a circuit makes a critical difference if a correct measurement is to be made. The current in each circuit was measured with a clamp-on ammeter, the voltage was measured with a multi-meter, and the resulting maximum power draw was calculated for each phase and the results compared with the readings from the hand-held terminal. If a discrepancy existed, the problem was traced down and corrected. The pulse output for each channel was counted for one minute and the appropriate calculations were made on site to compare these results with the previously described measurement. Pulses were counted on the LEDs mounted on the recorder and with a special counter that attached to the watt-hour transducer. Problems with reversed current transformers, bad transducers, and swapped phases were the most common. Once all of the channels had been verified for a site, it was then allowed to be initialized. Documentation of the measurements taken during the verification visits have been prepared.

DATA COLLECTION AND VALIDATION

The data collection starts with the recorder transferring its data to a DEC based ALICE 5 Data Acquisition System. The data for all channels are collected in 5 minute intervals. Every two weeks the data are transferred via a 9-track tape to another computer system where the validation of the data takes place.

A Data Validation System (DVS) software package that operates on PC-based hardware has been developed to allow "real time" data validation. DVS is designed to load monitored data into a data base, pass the data through an automated data validation routine, provide a means to view the data in graphical form, produce charts, and maintain the data base. A set of Master Files is used to specify information about each channel of data that is stored in the data base. The remainder of this paper will discuss the steps used by DVS and how they are used to insure the quality of the data.

DVS OPERATIONS

Once the 9-track data tapes are available, they are transferred to the micro-computer data base via a tape drive. However, before any data are transmitted to the data base, a Master File must be updated (to reflect new sites that may be present in the data) within the data base to direct the incoming data. The Master File consists of Device and Channel Identification forms. Here each recorder is referred to as a single device with a unique identification number. Each device contains up to four channels of different end-use monitoring data, each channel with a unique identification number. The Device Identification Form consists of information such as the site location, the number of channels it contains and the pulse interval size. The Channel Identification Form contains information such as the type of end-use monitored, minimum and maximum loads and different multipliers used for converting pulse data into engineering units. The channel form also includes the maximum number of consecutive zeros allowed for the channel. Such information is used for automated data verification, which takes place every time additional data are transferred to the data base.

The system assigns error flags, which appear on the graphical presentation as different colors, to data values which exceed the ranges specified in each respective channel ID master file. The data can be flagged for exceeding the maximum load or for going below the minimum load specified. An error flag is also assigned if a channel collects no pulses for a longer period of time than that specified by the maximum consecutive zero entries allowed in the device ID file. For example a refrigeration channel may have an acceptable no pulse period of only four hours while a lighting channel may collect no pulses for up to fourteen consecutive hours (overnight) and not be flagged as an error.

During the next stage, error exception reports are printed which give a listing of the number of errors found during automated validation for the newly transferred data for every channel in the

Master File and the specific times of occurrences for the different error types. The next step is viewing the data in its graphical form through the use of the Load Profile Viewer (LPV). The color graphs presented by LPV also include an average line for each channel which is superimposed on the newly transferred data as a guideline to show how the channel behaved in the previous weeks. The average line is a profile that is unique for every day of the week. It represents a cumulative running average for the number of weeks specified in the master file. The average profile acts as a template and is an important tool used to validate new data. An example of this is shown in Figure 2 where the average line appears as white as a contrast to the solid representation of the actual data that shows up as black.

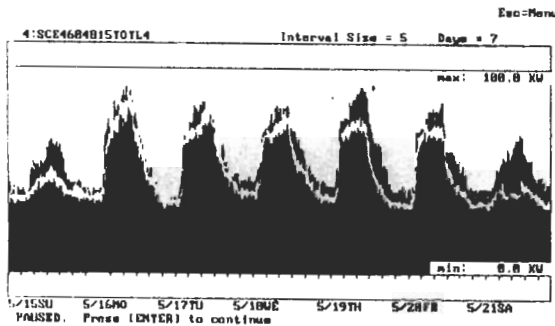


Fig. 2 Load Profile Viewer screen showing 7 days of Total Electric load for a Retail store showing the average file superimposed on the data as a white line.

LPV OPERATIONS

LPV offers various features which allow the data to be presented in different ways. A single channel can be presented with data anywhere from one day up to a full week of seven days. This can be viewed in the Animated mode, which lets the data scroll horizontally on the screen, or in the non-animated mode which presents the data in stationary screens. The data for all channels, (except temperature channels) can be viewed all at once through the use of the Summary Channel. An example of a summary channel illustrating one day worth of data is shown in Figure 3. Each line graph

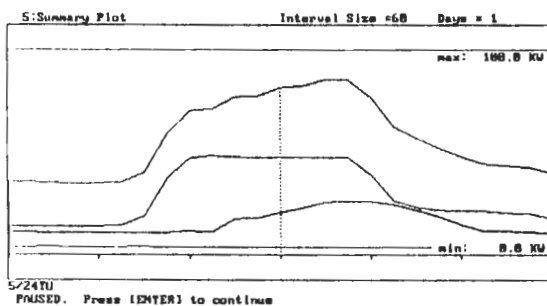


Fig. 3 LPV screen of a one day plot showing all four channels plotted with hourly data.

represents the data for an individual channel. A comparison of Figure 3 with Figure 4 highlights another feature of the LPV. This feature allows for the change of the interval size for the data to be graphed. In other words the data can be graphed in five minute, 15 minute, 30 minute or hourly intervals and this can be changed instantaneously. Figure 3 shows the data in hourly intervals while Figure 4 shows the same data further refined into 5 minute intervals, which produces more detail.

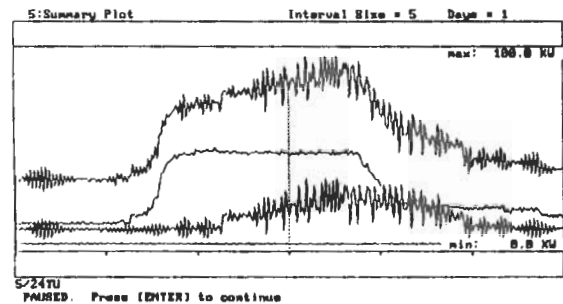


Fig. 4 LPV screen of a one day plot showing all four channels plotted with 5 minute data.

The data for the Total Channel are gathered by the LPR through the use of the pulse output of the billing meter and therefore represents the total electrical energy usage at the site rather than the summation of all the channels being monitored. Hence one should not expect the line graphs of other channels to add to equal the total channel's output while viewing the summary channel.

On the other hand, an error could be detected by noticing the relative changes of each channel. For example if the summary channel shows that the HVAC has dropped to zero and the other channels are relatively constant, then the Total channel must show a decrease at the time the HVAC shows no pulses. If not, then the data are invalid; an example of this is shown in Figure 5. Having the total channels fall to zero while other channels show recorded pulses is a definite sign of equipment failure and invalid data. Trouble can also be detected for a temperature transponder by viewing the respective Temperature channel. If there are sporadic range errors, or sudden temperature changes then there most likely is equipment malfunction which must be acted upon. An example of the temperature transponder sporadically failing to communicate with the receiver is shown in Figure 6. The high, off of the scale readings for temperature indicate that there were no pulses collected for that time period. As problems are found with the data, Trouble Reports are filled out to document problems in the data and to alert the electrical installers that a maintenance visit is required.

The data in this project are being validated nearly on a "real time" basis, with only a two week time lag in the data collection process. Examples of the profile data being collected are shown in Figures 7 and 8.

ELECTRICAL END-USE LOAD PROFILE

DEVICE ID: RESA09GRY2

DATE: 05/22/88

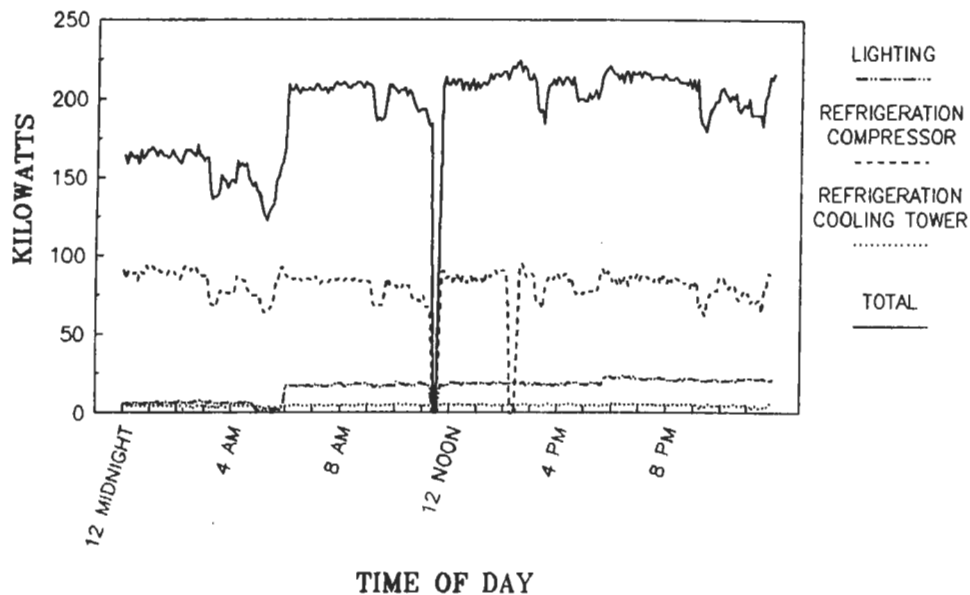


Fig. 5 One day plot of data from a grocery store showing two error conditions. A power loss occurred a 11:30 AM, and a loss of the transponder signal occurred at 2:30 PM on the refrigeration compressor channel.

ELECTRICAL END-USE LOAD PROFILE

DEVICE ID: RESA02RST1

DATE: 05/20/88

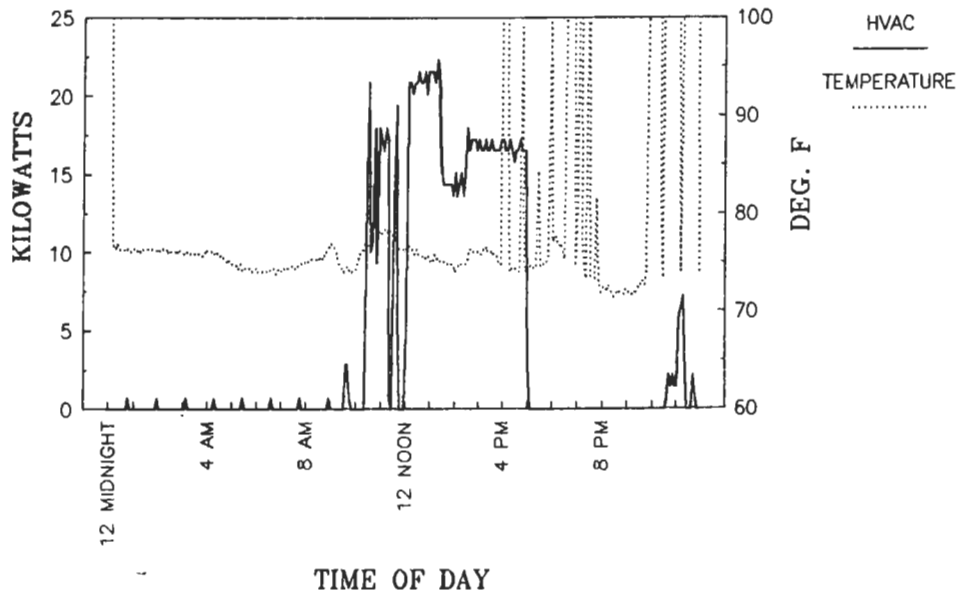


Fig. 6 One day plot showing bad temperature data occurring sporadically after 4 PM.

ELECTRICAL END-USE LOAD PROFILE

DEVICE ID: RESA06RST

DATE: 05/20/88

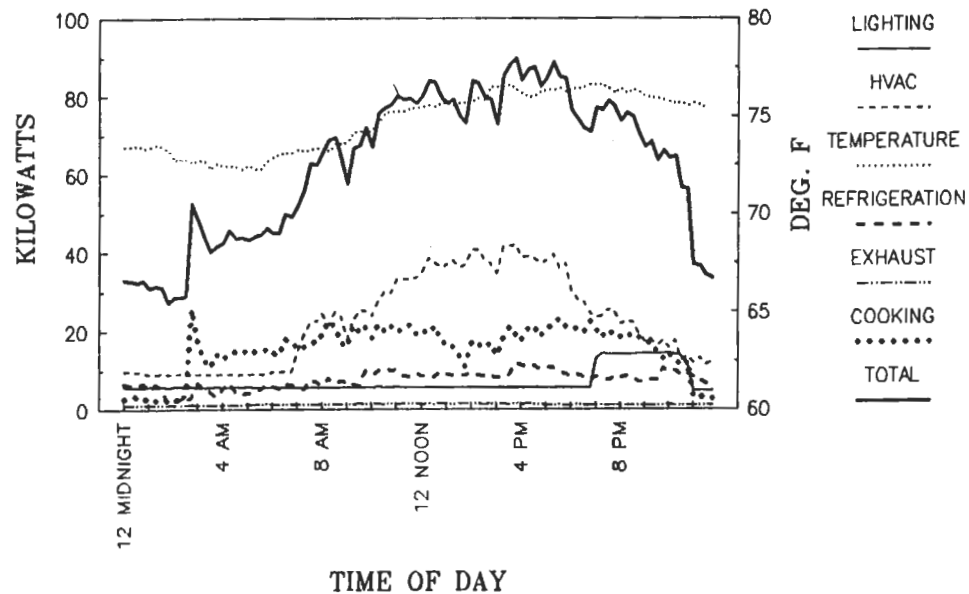


Fig. 7 Profile of a fast food Restaurant.

ELECTRICAL END-USE LOAD PROFILE

DEVICE ID: RESA01RTL1

DATE: 05/20/88

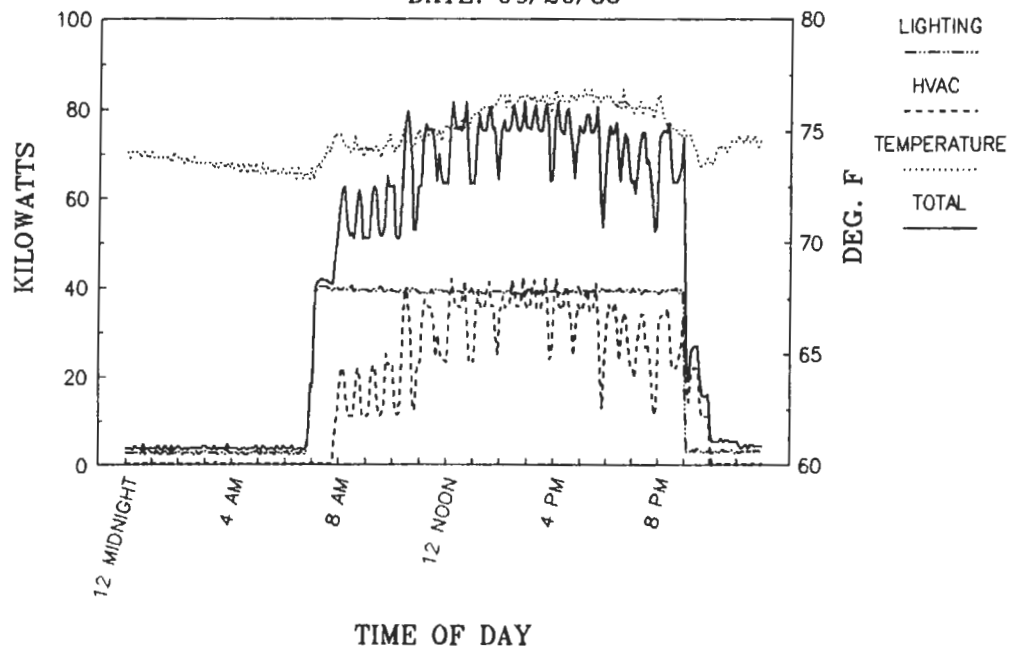


Fig. 8 Profile of a Retail Store.

CONCLUSION

This study is on the forefront of end-use data collection in commercial buildings because the data are being verified and validated on a state-of-the-art Data Validation System and in a timely manner. It has been shown that data can be validated on a "real time" basis so that the quality of the collected data can be maintained. Detailed information on these sites support the data that are being collected so that they can confidently be used for analysis.

These data provide a useful tool to researchers in studying electrical end-use load profiles. They provide data which, after being

properly analyzed, can be used to direct marketing strategies.

The data collection phase of the study was started in May 1988. The data collection for this study is scheduled to continue for two years. All data collected will pass through the Data Validation System.

As a result of the level of effort by all parties involved in this project, the capture rate for the data has been very high. To date 93 percent of the data has passed the validation criteria as good data, which is a much higher rate than has been achieved in any comparable data collection projects.